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OPTIMAL AIRFRAME SYNTHESIS
FOR GUST LOADS

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Introductory Remarks

The application of mathematical nonlinear programming algorithms has enjoyed considerable success in the automated structural synthesis environment. A sizeable majority of research pertaining to optimum structural design has primarily focussed on statically loaded structures. The addition of dynamic loading in the form of harmonic excitation (Ref. 1) or random loads (Ref. 2) to the structure introduces significant new problems. Since all aerospace vehicles operate in a dynamic loads environment, it is imperative that efficient automated structural sizing procedures be developed that adequately account for these complexities. Furthermore, an increasing focus on multidisciplinary design and optimization dictates a realistic representation of each participating discipline.

The optimum sizing of airframe structures is performed in a complex analysis environment where structural stability must be carefully monitored in addition to elastic deformation under static and dynamic loads. Hence an analysis tool that accounts for the interaction of structural deformations and unsteady airloads, is a necessary ingredient to the development of any synthesis capability. The present report documents the framework of an optimization system, developed around the ISAC computer program (Ref. 3), with SPAR (Ref. 4) and CONMIN (Ref. 5) as the structural analysis and optimization programs, respectively. The NOS control language feature on the CDC Cyber computer is used to direct the flow between various segments of the system. In its present form, the system retains a degree of modularity, permitting substitutions of the analysis packages.

The thrust of the present work was directed towards establishing an optimization capability for sizing airframe structures that are subjected to a combination of deterministic and random flight loads. The random vibration environment introduces the need for selecting a statistical process that best describes the random loads and permits computation of the dynamic response parameters of interest. Furthermore, it requires a formulation of design constraints that would minimize the conservativeness in the design and retain computational viability. In the present work, the random loads are treated as a stationary, homogeneous process with a Gaussian probability distribution. A frequency domain analysis is selected for the solution of the dynamic response problem. This permits a power spectral density input for the gust velocities, a representation that is typically available from experimental observations. The ISAC system of programs has the feature to incorporate arbitrary gust velocity input spectra.

Subsequent sections of this report discuss the formulation of the analysis problem, the structure of the optimization programming system and a representative numerical example. An appendix with procedure files and FORTRAN pre- and post-processor listings is included for completeness.

Dynamic Response Analysis

In a frequency domain analysis, the system equations of motion can be written as

$$(-\omega^2[M] + [K] - [A])\{W\} = \{G\} \quad (1)$$

where $[M]$ and $[K]$ are the mass and stiffness matrices, respectively; $\{W\}$ is the displacement vector; $[A]$ is the matrix of loads due to oscillation at frequency ω , and $\{G\}$ is the force coefficient array per unit gust velocity. As is typical of large structural configurations, a modal approach is adopted wherein a finite number of elastic modes are used to model the structural deformations. The displacement $\{W\}$ can be represented approximately by the superposition of the characteristic modes

$$\{W\} = [\phi] \{\xi\} \quad (2)$$

where $[\phi]$ is the matrix of 'm' normalized eigenmodes and $\{\xi\}$ is an m-dimensional vector of generalized coordinates. Substituting equation (2) into equation (1) and then transforming the resulting equation from the frequency domain into the Laplace domain yields the equations of motion in the following form

$$[M_{\xi\xi}s^2 + (1 + ig)M_{\xi\xi}\omega_{\xi}^2 - A_{\xi\xi}]\{\xi\} = \{\bar{G}\} \quad (3)$$

where $M_{\xi\xi}$ is the generalized mass matrix; $A_{\xi\xi}$ and \bar{G} are the generalized aerodynamic force matrices due to motion and gust respectively; g is the structural damping coefficient and ω_{ξ}^2 is the natural frequency associated with the ξ -th generalized coordinate. Equation 3 is a system of linear, nonhomogenous equations that are solved for the vector of generalized coordinates. A similar approach can be adopted to include a control surface, and the option to do so exists in the ISAC system.

Typical response parameters for which design constraints can be formulated include stresses, nodal displacements, and accelerations at specified locations. The focus of the present work was in implementing structural reliability constraints for which element stresses are the primary response quantities of interest. In the modal displacement approach, the stress at a location j is computed as

$$S_j = \sum_i c_{ij}\xi_i \quad (4)$$

where c_{ij} is the stress coefficient at location 'j' due to a unit displacement in the i-th generalized coordinate ξ_i . For a random gust input, these quantities are obtained as root mean square (rms) values which are then used in the constraint formulation.

Structural Reliability Constraints

For a structure subjected to random gust loads, failure can be caused by a single overstress or as a result of cumulative damage in fatigue. These failure conditions are termed by Johnson (Ref. 6) as single excursion and fatigue,

respectively. Constraints must be formulated for both these failure modes. For a stress response $S(t)$ that is stationary and has a Gaussian probability distribution, an assumption that large values of $S(t)$ arrive independently, leads to a Poisson probability function for the number of times 'n' that a large magnitude \bar{S} is exceeded in time 't'. If the occurrence of this large stress magnitude is not permitted in time T_s , the single excursion constraint, $g_{S.E}$, can be written as

$$g_{S.E} = \frac{T_s}{\pi} \frac{\sigma_s^*}{\sigma_s} \exp \left(- \frac{\bar{S}^2}{2 \sigma_s^2} \right) - 1 \leq 0 \quad (5)$$

Fatigue damage can be estimated on the basis of the Palmgren-Miner theory and results in a fatigue constraint, g_F , of the following form

$$g_F = \frac{\sigma_s^{*L_f}}{\pi c} (2)^{\frac{b-2}{2}} \sigma_s^{b-1} \Gamma \left(\frac{b+2}{2} \right) - 1 \leq 0 \quad (6)$$

where, L_f is the specified fatigue life; Γ is the gamma function; σ_s and σ_s^* are the rms values of the stress and stress rates and b and c are constants obtained from empirical relations for different materials.

Failure constraints derived from a fracture mechanics standpoint have also been proposed (Ref. 7) where the constraints expressed in equations (5) and (6) are essentially unified into a single constraint. The initiation and propagation of cracks in a material results in both a reduced allowable stress and can also be viewed as accumulated damage in the structure. In the present work constraint equations (5) and (6) were implemented in the design.

Optimization System

This section of this report gives a brief description of the optimization system and its component programs. The optimization system combines a finite element program SPAR, a general-purpose, nonlinear programming-based optimization program CONMIN, and a system of aeroelastic response analysis programs ISAC. The flow between these programs is controlled in a manner similar to the PROSSS system for optimum design (Ref. 8). The role of each of these programs is discussed next. The reader is referred to Appendix A for a listing of the various routines described in this section.

SPAR

The program is a system of independent processors which communicate with each other through a data base which consists of libraries of named data sets. The structural model geometry definition, material specification and element connectivity are defined in a SPAR input runstream NREPT, and the data set library is stored as NRLA. This is the non-repeatable part of the structural analysis program and does not have to be re-executed as the program iterates in the optimization mode. The SPAR program is used to generate for the ISAC system, quantities such as mode-shapes, eigenvalues, generalized masses and stress coefficients defined in equation (4). It is also used to generate finite-difference

gradients for the eigenmodes and frequencies. A FORTRAN program GRAD generates an input runstream corresponding to the set of new design variables. This input runstream, SECPROP, is executed before the repeatable segment REPT is called to obtain the new response parameters. A FORTRAN program EIGSTR employs the SPAR data handling utilities (Ref. 9) to extract the desired information from the data set libraries and store the information for post processing.

ISAC

The ISAC system of routines is employed to compute the aeroelastic response of the flight vehicle. The structural node deflections corresponding to the vibration modes obtained in SPAR are related to the deflections and slopes on aerodynamic boxes by a 2-D, spline interpolation technique in DLIN. These aerodynamic slopes and deflections are used by a doublet lattice program DLAT, in the computation of the generalized aerodynamic forces for a range of reduced frequencies. The generalized mass, stiffness and aerodynamic matrices are passed to the routine DYNARES where a gust spectrum is selected and the aeroelastic response parameters are obtained. For a random gust input, the rms responses can be computed by numerical integration of the response spectra within this routine. In the present organization, however, DYNARES writes a state space representation of the system equations and passes the system matrices to another group of programs PADLOCS (Ref. 10), where the rms responses are computed. Additionally, this program provides correlation coefficients between various response components which are required in the formulation of stress constraints in the event of a combined stress failure criterion (Ref. 11). The input files required for ISAC execution are listed in Appendix A. For a detailed description of the input parameters, the reader is referred to Reference 3.

CONMIN

CONMIN is a general purpose optimization subroutine for solving constrained and unconstrained, linear or nonlinear, continuous problems. It is based on the method of feasible-usable search directions (Ref. 5) and was adapted in the present framework in a piecewise linear mode of operation. The general optimization problem for CONMIN can be posed as follows

Minimize a function

$$F(d_1, d_2, \dots, d_n) \quad (7)$$

Subject to the inequality constraints

$$g_j(d_1, d_2, \dots, d_n) \leq 0 \quad j = 1, 2, \dots, m \quad (8)$$

and the side constraints on the design variables d_i

$$d_i^l \leq d_i \leq d_i^u \quad i = 1, 2, \dots, n \quad (9)$$

In general, both the objective function and constraints can be nonlinearly dependent on the design variables. In a piecewise linear mode of operation, the objective function and design constraints are regarded to be linear functions of the design variables, eliminating the need to compute function derivatives at

every iteration for a general nonlinear problem. A linear approximation to a general nonlinear problem requires that constraints be imposed on design variable change for a given cycle of optimization. An appropriate choice of design variables (reciprocal variables) will often enhance the linearity in the design space.

Program Organization

A flow chart depicting the implementation of the optimization system is shown in Figure 1. The corresponding procedure file PRLLOOP is listed in Appendix A. The structural model is initialized for the starting design and the eigenmodes, natural frequencies and response coefficients and their sensitivity to perturbations in design variables are computed. This information is then used to compute the response constraints sensitivity in a finite difference operation. The two sensitivity computations were separated on purpose. If the eigenvalue and eigenvector sensitivities are assumed constant, the outer gradient loop can be executed once in the optimization sequence. The inner gradient loop for constraint sensitivities is the only required operation for subsequent cycles of optimization. By the same token, if the eigenvalue/eigenmode sensitivities are known to be more nearly constant over a wider variation in design variables, the outer loop can be executed a lesser number of times in the optimization sequence. The objective function, constraints and their gradients are passed to an optimization program where the design variables are altered within the limits imposed by the side constraints. This sequence is repeated until convergence.

Numerical Examples

A built up finite element model of a wing structure was developed as a test problem for the program implementation described in the preceding sections. The cross-section and planform of this stringer-membrane, cantilever structure is shown in Figures 2 and 3. The model element sizes were preprocessed by a fully-stressed design cycle for 1-g cruise loads. These member sizes were established as the lower bounds for the gust design. A Dryden spectrum with a gust intensity of 2.54 m/sec (typical of storm conditions) was specified in the input. The first six elastic modes were chosen to represent the structural deformation and were considered adequate for such a cantilever structure. In more realistic designs for gust loads, rigid body modes in plunge and pitch should also be included. The addition of these in the present system constitutes no added complexity. The design variables selected for this minimum weight design were the cross-sectional areas of the bar elements. An allowable stress of 1761.4 kg/cm² was used in the computation of the first excursion failure constraints. First excursion and fatigue failure lives of 2 years were specified in the design process. The design converged in 13 piecewise linear cycles to the values shown in Table 1. The first cantilever mode in bending dominates the stress distribution in the structure, as is evidenced by a concentration of material at the root section. The first excursion constraint is active at the optimum.

Concluding Remarks

This report documents the development and implementation of an optimization system around ISAC for the structural design of airframe structures with aeroelastic constraints. The programming system is regarded as the necessary first

step for further studies in the systematic design of aircraft structures, operating in a random gust load environment. Although developed primarily for the design of structures under random gust loads, the program in its present form is suitable for inclusion of static stress, displacement and frequency constraints. An s-plane formulation of the flutter constraint can also be added with minor modifications. These features coupled to a built-in control analysis capability, make this programming system an extremely powerful tool for multidisciplinary analysis and design. Furthermore, the programming system provides a natural test-bed for multilevel optimization studies. The computational efficiency of the system can be significantly enhanced with the inclusion of an analytical gradient capability.

References

- (1) Cassis, J. H.: Optimum Design of Structures Subjected to Dynamic Loads. UCLA-ENG-7451, UCLA, School of Engineering and Applied Science, June 1974.
- (2) Hajela, P.: Comments on Gust Response Constrained Optimization. NASA CP 2327, April 1984.
- (3) Peele, E. L., and Adams, W. M., Jr.: A Digital Program for Calculating the Interaction Between Flexible Structures, Unsteady Aerodynamics and Active Controls. NASA TM 80040, January 1979.
- (4) Whetstone, W. D.: SPAR Structural Analysis System Reference Manual - System Level 13A, Volume 1 Program Execution. NASA CR 158970-1, 1978.
- (5) Vanderplaats, G. N., and Moses, F.: Structural Optimization by Methods of Feasible Directions. Computers and Structures, Vol. 3, 1973, pp. 739-755.
- (6) Johnson, E. H.: Optimization of Structures Undergoing Harmonic or Stochastic Excitation. SUDAAR No. 501, Stanford University, August 1976.
- (7) Hajela, P., and Lamb, A.: Optimum Structural Design Under Stochastic Loading Conditions. Proceedings of the Tenth Canadian Applied Mechanics Congress, June 2-7, 1985, pp. D-7, 8.
- (8) Rogers, J. L., Jr., Sobieski, J. E., and Bhat, R. B.: An Implementation of the Programming Structural Synthesis System (PROSSS). NASA TM 83180, December 1981.
- (9) Giles, G. L., and Haftka, R. T.: SPAR Data Handling Utilities. NASA TM 78701, September 1978.
- (10) Newsom, J. R., et al: Active Controls: A Look at Analytical Methods and Associated Tools. NASA TM 86269, July 1984.
- (11) Gross, D. W., and Sobieski, J. E.: Application to Aircraft Design of Nonlinear Optimization Methods Which Include Probabilistic Constraints. Presented at the 18th AIAA Aerospace Sciences Meeting, San Diego, CA, January 1980, AIAA Preprint No. 80-0153.

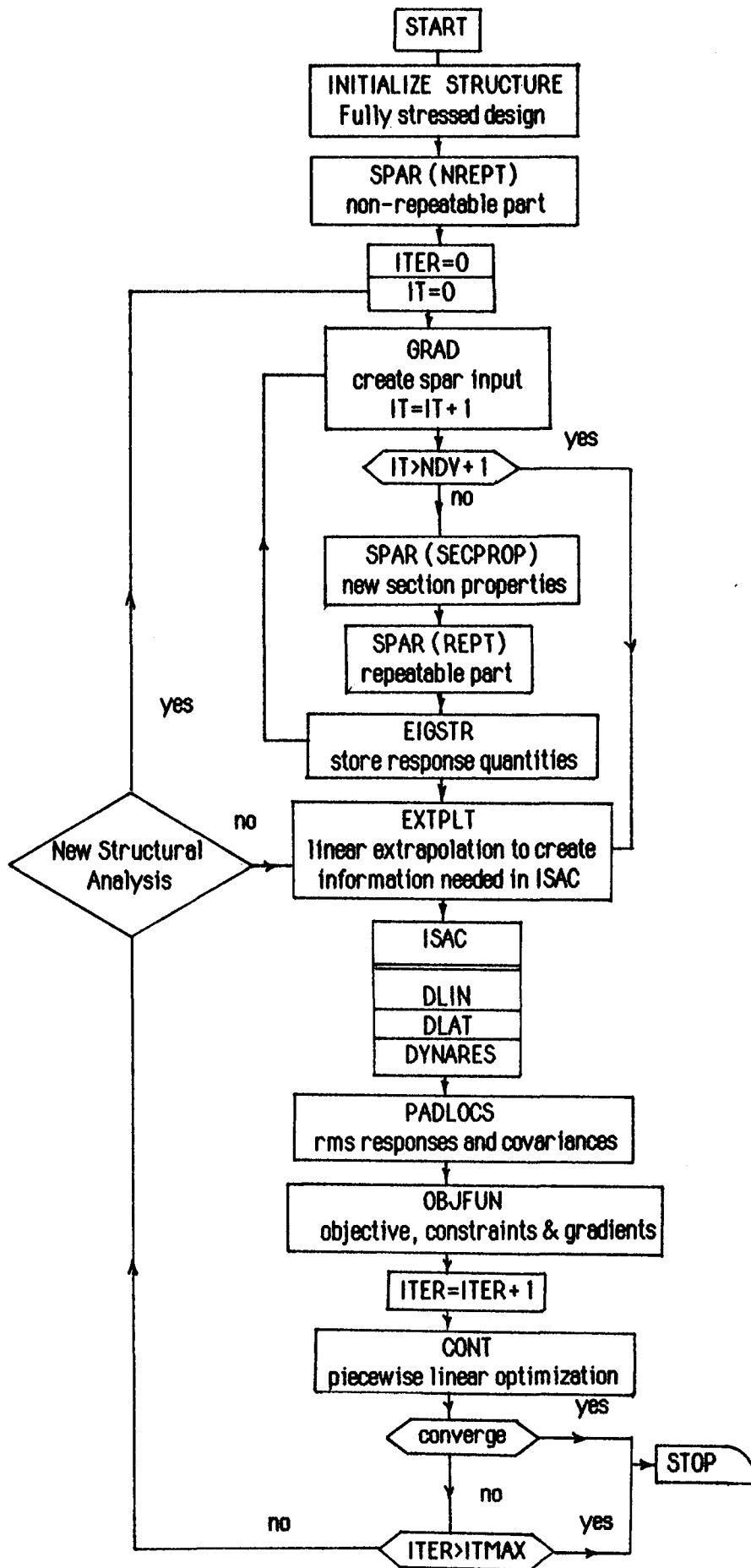


Figure 1. Flowchart depicting the organization of the optimization system

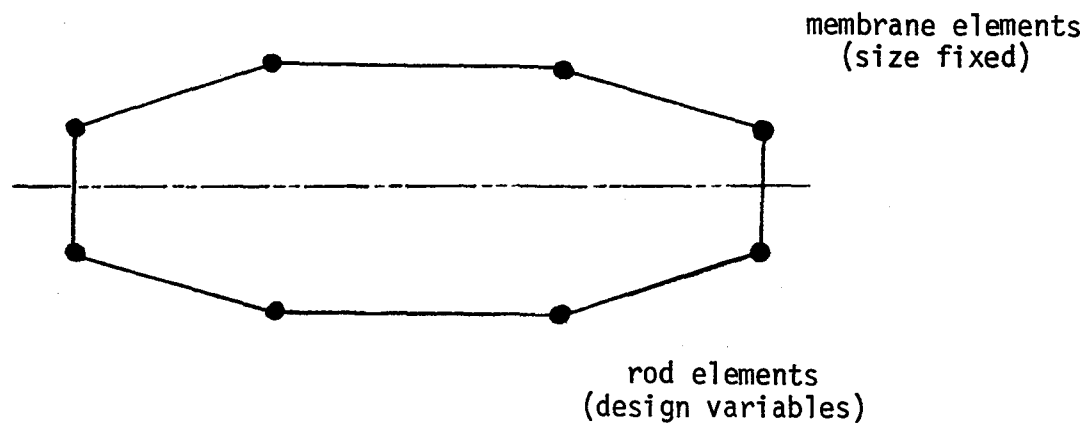


Figure 2. Cross section of wing structural box

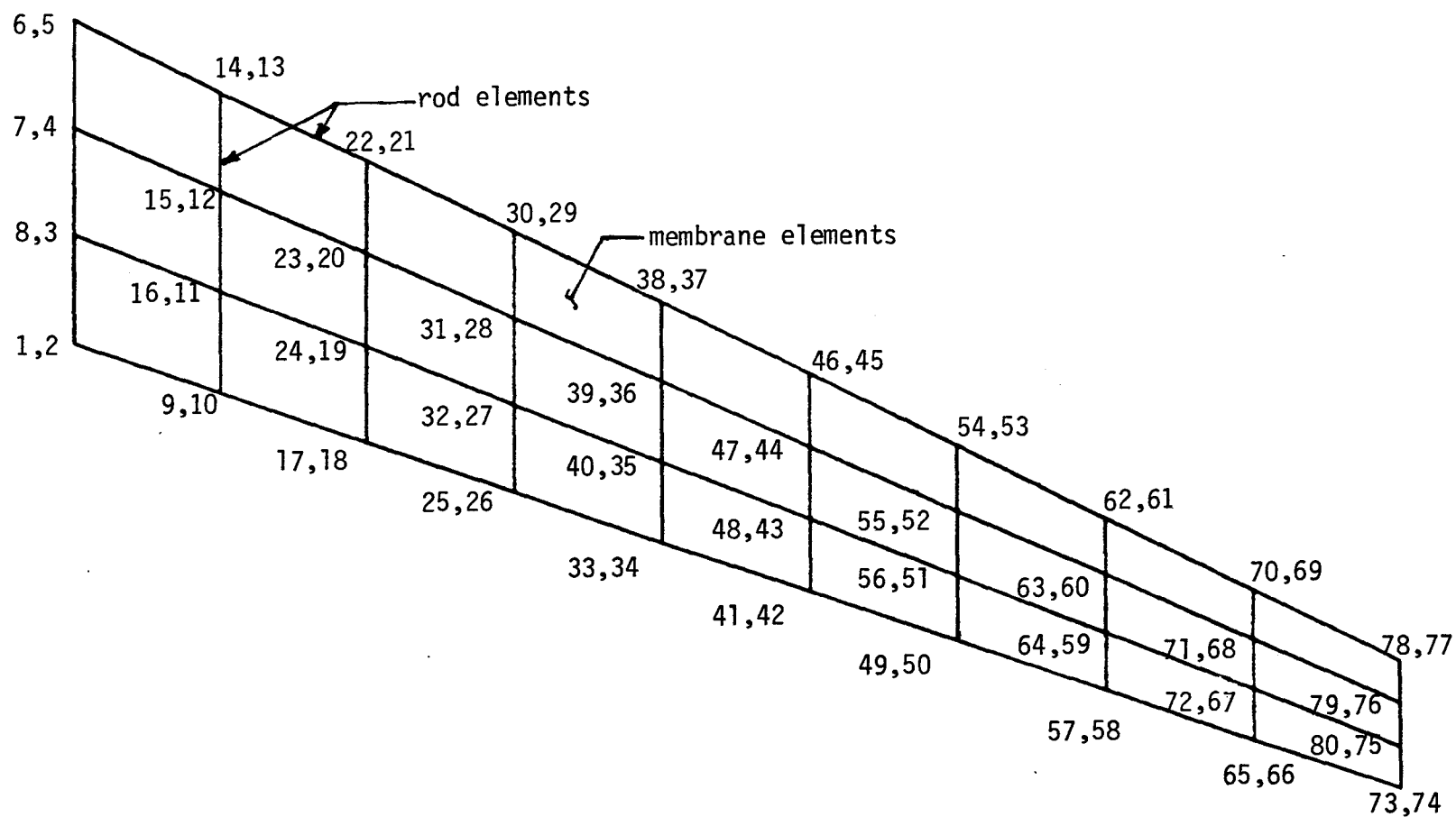


Figure 3. Finite element model of Wing Structural Box. Node numbers n1, n2 represent lower and upper surface co-ordinates, respectively. Panel elements were sized by a fully-stressed design approach.

Design Variable	Element Connectivity	Initial Design (cm ²)	Minimum Gage (cm ²)	Final Design (cm ²)
1	1-9,9-17,8-16,16-24 7-15,15-23,6-14,14-22	10.3226	10.1096	17.9516
2	17-25,25-33,24-32,32-40 22-30,30-38,23-31,31-39	10.3226	4.6297	9.4458
3	33-41,41-49,40-48,48-56 39-47,47-55,38-46,46-54	10.3226	0.6452	2.5239
4	2-10,10-18,3-11,11-19 4-12,12-20,5-13,13-21	10.3226	10.1096	17.9574
5	18,26,26-34,19-27,27-35 20-28,28-36,21-29,29-37	10.3226	4.6309	9.5703
6	34-42,42-50,35-43,43-51 36-44,44-52,37-45,45-53	4.516	0.6452	2.5298
7	54-62,62-70,70-78 55-63,63-71,71-79 56-64,64-72,72-80 49-57,57-65,65-73	4.516	0.6452	1.1761
8	53-61,61-69,69-77 52-60,60-68,68-76 51-59,59-67,67-75 50-58,58-66,66-74	4.516	0.6452	0.9661
Objective Function Weight		286.33 Kg	195.56	270.41 Kg

Table 1. Numerical results for the cantilevered wing structural box

Appendix A

```
LIST, FN=SUBFIL
PRLOOP, T6000.
USER, 358625C, PATHA.
CHARGE, 102632, LRC.
DELIVER.1229 PH PROC TEST CASE
*
*  THIS FILE IS  PRLOOP
*
MAP, OFF.
BEGIN, PRLOOP.
COPYSBF, INPUT, OUTPUT.
DAYFILE, L=DAYPRLP.
REPLACE, DAYPRLP.
EXIT.
COPYSBF, INPUT, OUTPUT.
DAYFILE, L=DAYPRLP.
REPLACE, DAYPRLP.
EOI ENCOUNTERED.
/
```

Above procedure file is used to initiate a batch run for optimization.

PROCFIL is a listing of all procedure files used in the present optimization system.

```
LIST, FN=PROCFIL
.PROC, DYNA.
GET, DCM=DCMV2A/UN=887010N.
GET, DYNARES=DYNAV3A/UN=887010N.
REVERT.
.PROC, CONT.
GET, CONMINB/UN=753437N.
GET, CONB.
COPYBR, CONB, PRAT.
COPYBF, CONMINB, PRAT.
GET, DESIGN, OLDOBJ, CONMDT, CONPAR.
REWIND, *.
PRAT.
REWIND, TAPE6.
APPEND, CONOUT, TAPE6.
REPLACE, OLDOBJ.
REPLACE, DESIGN.
REVERT.
.PROC, OBFUN.
RETURN, *.
GET, OBJFUB, DECIS, ITER, DESIGN, CVD1, OBDJ.
PACK, CVD1.
OBJFUB.
REPLACE, CONMDT.
RETURN, *.
REVERT.
.PROC, DYNDDES.
GET, TAP2G.
BEGIN, DYNA.
BEGIN, PRDES.
BEGIN, DYNA.
BEGIN, PRDES.
BEGIN, DYNA.
BEGIN, PRDES.
BEGIN, DYNA.
BEGIN, PRDES.
BEGIN, DYNA.
BEGIN, PRDES.
BEGIN, DYNA.
BEGIN, PRDES.
BEGIN, DYNA.
BEGIN, PRDES.
BEGIN, DYNA.
BEGIN, PRDES.
BEGIN, DYNA.
BEGIN, PRDES.
BEGIN, DYNA.
BEGIN, PRDES.
REVERT.
.PROC, PRGUST.
GET, TAPES=POUT.
```

```

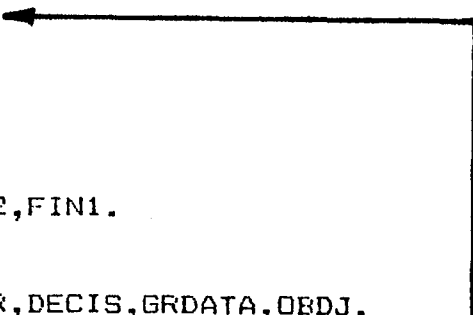
BEGIN,DCM.
DCM,,,,,DCMIN1.
RETURN,DCM,TAPE5.
REWIND,TAPE9.
REPLACE,TAPE9=PHT9.
BEGIN,DLIN.
GET,TAPE1=W2POS1,TAPE3=TAPE31,TAPE5.
DLIN.
REWIND,*.
RETURN,TAPE1,TAPE3.
GET,TAPE1=W2POS2,TAPE3=TAPE32.
DLIN.
REWIND,*.
RETURN,TAPE1,TAPE3.
GET,TAPE1=W2POS3,TAPE3=TAPE33.
DLIN.
REWIND,*.
REPLACE,TAPE9=PHT9.
RETURN,*.
REVERT.
.DATA,DCMIN1.
BATCH
STORE
GMASS -1 1 324 1
F
GENERALIZED MASSES
STORE
FREQ -1 1 18 1
F
FREQUENCIES IN HZ
STORE
LOADS -1 1 1296 1
F
STRESS COEFFICIENTS
STORE
DAMPINGS -1 1 18 1
F
DAMPING COEFFICIENTS
STORE
GMASS -1 2 324 1
F
GENERALIZED MASSES
STORE
FREQ -1 2 18 1
F
FREQUENCIES IN HZ
STORE
LOADS -1 2 1296 1
F
STRESS COEFFICIENTS
STORE
DAMPINGS -1 2 18 1
F
DAMPING CONSTANTS
STORE

```

```

GMASS -1 3 324 1
F
GENERALIZED MASSES
STORE
FREQ -1 3 18 1
F
FREQUENCIES IN HZ
STORE
LOADS -1 3 1296 1
F
STRESS COEFFICIENTS
STORE
DAMPINGS -1 3 18 1
F
DAMPING CONSTANTS
END
.PROC,PRDES.
GET,TAPE9=PHT9.
COPYBR,TAP2G,TAPE2.
REWIND,TAPE2.
DYNARES.
REPLACE,TAPE1=TAPE7.
RETURN,*,TAP2G.
GET,DESDAT,TAPE7,DESIGN=DEZIGN.
DESIGN,DESDAT.
REWIND,CVDATA.
GET,REDUB.
REDUB.
APPEND,CVD1,CVDATA.
RETURN,*,TAP2G.
REVERT.
.PROC,PREXT.
GET,EXTPLB,DECIS,DESIGN,CONDAT,ITER,NODAL.
REWIND,*.
EXTPLB.
REWIND,*.
REPLACE,WPOS=W2POS1,WPOS1=W2POS2,WPOS2=W2POS3.
REPLACE,POUT.
REVERT.
.PROC,STORE.
GET,EIGSTRB,ITER,GRDATA,LOO1=RRLA.
REWIND,*.
EIGSTRB.
REPLACE,GRDATA.
REVERT.
.PROC,PRLOOP.
SET(R2=10)
SET(R3=0)
1OPT,CTIME.
SET(R1=0)
MAP,OFF.
WHILE,R1.LT.R2,FIN1.
SET(R1=R1+1)
DISPLAY(R1)
GET,GRADB,ITER,DECIS,GRDATA,OBJD.
GRADB.

```




```

REPLACE,ITER,CONDAT,OBJD.
RETURN,GRDATA.
IFE,R1.LT.R2,JMP1.
BEGIN,PRRSPAR.
BEGIN,STORE.
RETURN,*
ENDW,FIN1.
ENDIF,JMP1.
BEGIN,PREXT.
BEGIN,PRGUST.
GET,TAPE5=TAPEST,TAPE9=PHT9.
BEGIN,DLAT.
ALPHA.
REPLACE,TAPE9=PHT9.
RETURN,*
BEGIN,DYNDES.
BEGIN,OBJFUN.
GET,CVD1=CV.
REPLACE,CVD1.
SET(R3=R3+1)
BEGIN,CONT.
GET,DECIS,DESIGN,ITER,POSB.
POSB.
REPLACE,DECIS.
IFE,R3.LT.9,JMP2.
IFE,FILE(IFLG,.NOT.AS),JMP3.
RETURN,*
GOTO,10PT.
ENDIF,JMP2.
ENDIF,JMP3.
REVERT.

```

PRLOOP is the procedure file
to execute the various segments
of the optimization sequence.

```

.PROC,PRCSTR,XXX=W2ZPOS.
*
* EXECUTE THIS PROCEDURE AS FOLLOWS:
* -DLNPROC,DLNPROC.
*
RETURN,LGO.
GET,DLNLIB.
*PUT HERE A GET TO YOUR TAPES - INPUT FILE
*NEXT MAKE AVAILABLE A SPAR FILE WHICH TO EXTRACT DATA FROM
GET,LOO1=RRLA.
GET,X=EIGSTR.
GET,GRDATA,ITER.
REWIND,X,ITER,GRDATA.
FTN,I=X,L=0,OPT=0,STATIC.
GTR,LGO,LL.REL/EIGSTR
GTR,DLNLIB,LL.REL/BLKDAT.
RENAME,LGO=LL.
LDSET(LIB=DLNLIB,MAP=SBEX/OUT)
LOAD,LGO.
NOGO(EIGSTRB).
REVERT.
.PROC,PRRSPAR.
.*
.* REPEATABLE SPAR
.*

```

```

GET,SPAR=SPAR14I,DCU=DCU14I/UN=750756N.
GET,SPARLA=NRLA.
REWIND,SECPROP.
SPAR,SECPROP,SPOUT.
RETURN,SPOUT.
REWIND,*.
GET,REPT.
SPAR,REPT,SPOUT.
REWIND,SPARLA.
REPLACE,SPARLA=RRLA.
RETURN,*.
REVERT.
.PROC,PRNSPAR.
.*
.* NONREPEATABLE SPAR
.*
GET,SPAR=SPAR14I,DCU=DCU14I/UN=750756N.
GET,NREPT.
SPAR,NREPT,SPOUT.
REPLACE,SPARLA=NRLA.
RETURN,*.
REVERT.
.PROC,DLIN.
GET,DCM=DCMV2A/UN=887010N.
GET,DLIN=DLINV3A/UN=887010N.
REVERT.
.PROC,DLAT.
GET,DCM=DCMV2A/UN=887010N.
GET,ALPHA=DLATV5A/UN=887010N.
REVERT.
.PROC,DCM.
GET,DCM=DCMV2A/UN=887010N.
REVERT.
.PROC,PLOT.
REWIND,SAVPLT.
PLOT,TEKPOST,TE(AUTO(0)).
NOTE./:G507>
REVERT.  WHAT A CRUMMY PLOT!!
.PROC,PLTRVAX.
REWIND,SAVPLT.
PLOT,TEKPOST,TE(AUTO(0).RVAX).
NOTE./:G507>
REVERT.
  EOI ENCOUNTERED.
/

```

```

LIST, FN=CONT
      PROGRAM CONOPT (CONPAR, OLDOBJ, DESIGN, CONMDT, IFLG,
      *TAPE56=CONPAR, TAPE12=OLDOBJ,
      *TAPE31=DESIGN, TAPE22=CONMDT, TAPE14=IFLG, OUTPUT,
      *TAPE6)
C
C *****
C
C THIS IS THE OPTIMIZER WITH PIECEWISE LINEAR APPROXIMATION
C
C PRABHAT HAJELA JUNE 1985
C
C *****
C
      COMMON/CNMN1/DELFUN, DABFUN, FDCH, FDCHM, CT, CTMIN, CTL, CTLMIN,
      *ALPHAX, ABOBJ1, THETA, OBJ, NDV, NCON, NSIDE, IPRINT, NFDG, NSCAL, LINOBJ,
      *ITMAX, ITRM, ICNDR, IGOTO, NAC, INFO, INFOG, ITER
      COMMON/CNMN2/RDUM(50), IDUM(50)
      COMMON/CONSAV/REAL(50), INT(25)
      DIMENSION X(50), VLB(50), VUB(50), G(200), SCAL(50),
      *DF(50), A(50,200), S(50), G1(200), G2(200), B(200,200),
      *C(200), ISC(200), IC(200), MS1(400)
      DIMENSION VLBTMP(50), VUBTMP(50), XINIT(50), GI(200),
      *GRDG(50,200), GRDOBJ(50)
      DATA NDV/8/, NCON/144/
C
C
C COMPUTE CONMIN DIMENSIONS
C
      NLIM1=NDV+1
      N1=NDV+2
      N2=NCON+2*NDV
      N3=N2+5
      N4=MAX0(N3, NDV)
      N5=2*N4
C
C
C READ CONMIN PARAMETERS
C
      READ(56,*) NITER, IPRINT, NSIDE, NFDG, LINOBJ, ITMAX, ICNDR, NSCAL,
      *ITRM, IGOTO, NDV, NCON, FDCH, FDCHM, CT, CTMIN, CTL, CTLMIN, THETA, PHI,
      *DELFUN, DABFUN, ALPHAX, ABOBJ1
C
C READ OLD OBJECTIVE FUNCTION VALUES
C
      READ(12,*) OBJ1, OBJ2, OBJ3, TOL
C
      DO 5 I=1, NCON
      ISC(I)=0
C
C PRESCRIBE BOUNDS ON DESIGN VARIABLES FOR OVERALL OPTIMIZATION
C

```

```

        VLBTMP(1)=1.567
        VLBTMP(2)=0.7176
        VLBTMP(3)=0.1
        VLBTMP(4)=1.567
        VLBTMP(5)=0.7178
        VLBTMP(6)=0.1
        VLBTMP(7)=0.1
        VLBTMP(8)=0.1
        DO 6 I=1,NDV
        VUBTMP(I)=5.0
6      CONTINUE
C
C      READ INITIAL DESIGN VARIABLES
C
        READ(31,*)(XINIT(I),I=1,NDV)
C
C      PRESCRIBE BOUNDS FOR LOCAL OPTIMIZATION CYCLE
C
        DO 12 I=1,NDV
        VUB(I)=1.4*XINIT(I)
        VLB(I)=0.6*XINIT(I)
        X(I)=XINIT(I)
        IF(VUB(I).GT.VUBTMP(I))VUB(I)=VUBTMP(I)
        IF(VLB(I).LT.VLBTMP(I))VLB(I)=VLBTMP(I)
12     CONTINUE
C
C      READ INITIAL FUNCTION AND GRADIENT INFORMATION
C
        READ(22,*)(GI(I),I=1,NCON),OBJ1
        *,((GRDG(I,J),I=1,NDV),J=1,NCON),
        *(GRDOBJ(I),I=1,NDV)
        OBJ=OBJ1
100    CONTINUE
C
C      CALL TO CONMIN OPTIMIZER
C
        CALL CONMIN(X,VLB,VUB,G,SCAL,DF,A,S,G1,G2,B,C,
        *ISC,IC,MS1,N1,N2,N3,N4,N5)
C
        IF(IGOTO.EQ.0)GO TO 555
        IF(INFO.EQ.2)GO TO 24
C
C      FUNCTION AND CONSTRAINT VALUES
C
        SUM=OBJ1
        DO 23 I=1,NDV
        DX=X(I)-XINIT(I)
        SUM=SUM+GRDOBJ(I)*DX
23     CONTINUE
        OBJ=SUM
        DO 22 J=1,NCON
        SUM=GI(J)
        DO 21 I=1,NDV
        DX=X(I) - XINIT(I)
21     SUM=SUM+GRDG(I,J)*DX*(XINIT(I)/X(I))
        G(J)=SUM
22     CONTINUE
        GO TO 100
24     CONTINUE

```

```

C
C GRADIENT INFORMATION
C
      DO 25 I=1,NDV
25    DF(I)=GRDOBJ(I)
      NAC=0
      DO 26 J=1,NCON
      IF(G(J).LT.CT)GO TO 26
      NAC=NAC+1
      IC(NAC)=J
26    CONTINUE
      DO 27 I=1,NDV
      DO 28 J=1,NAC
      J1=IC(J)
      A(I,J)=GRDG(I,J1)
28    CONTINUE
27    CONTINUE
C
      GO TO 100
C
C TERMINATE OPTIMIZATION LOOP
C
555  CONTINUE
      REWIND 31
      WRITE(31,*)(X(I),I=1,NDV)
C
C TEST FOR CONVERGENCE OVER THREE CYCLES
C
      OBJ3=OBJ2
      OBJ2=OBJ1
      OBJ1=OBJ
      REWIND 12
      WRITE(12,*)OBJ1,OBJ2,OBJ3,TOL
      IF(ABS(OBJ2).LE.0.0001)GO TO 666
      DA=ABS((OBJ3-OBJ2)/OBJ2)
      DB=ABS((OBJ2-OBJ1)/OBJ2)
C
C TERMINATE PROGRAM
C
      IF(DA.GT.TOL.OR.DB.GT.TOL)GOTO 666
      WRITE(14,*)NCON
666  CONTINUE
      STOP
      END
      EOI ENCOUNTERED.
/

```

```

LIST,FN=EIGSTR
      PROGRAM EIGSTR (GRDATA,ITER,TAPE2=ITER,TAPE32=GRDATA,
      *OUTPUT)
C
C *****
C
C   THIS PROGRAM READS AND STORES THE DATA REQUIRED FOR
C   THE EIGENANALYSIS AND STRESS COEFFICIENT GRADIENTS
C
C   PRABHAT HAJELA   JUNE 1985
C
C *****
C
      DIMENSION G1(100),G2(13000),G3(10000),G4(10),X(10),Y(10)
      DIMENSION AMODE(3,80),FREQ(25),STRS(72,6,1),STR1(10000)
      DATA NLIB/1/,NMODE/6/,ND41/10/,NSTR/72/,PI/3.14159/
      *,NMODE/80/,NELT/72/,NDOF/240/
C
C   READ FREQUENCY
C
      CALL DAL (NLIB,11,FREQ,0,0,KADL,IERR,NW,NE,LB,IT,
      *4HVIBR,4HEVAL,4HMASK,4HMASK)
C
C   STRESS COEFFICIENTS
C
      CALL DAL (NLIB,11,STR1(1),0,0,KADL,IERR,NW,NE,LB,IT,
      1 4HSTRS,4HE23 ,1,1)
      CALL DAL (NLIB,11,STR1(433),0,0,KADL,IERR,NW,NE,LB,IT,
      1 4HSTRS,4HE23 ,1,2)
      CALL DAL (NLIB,11,STR1(865),0,0,KADL,IERR,NW,NE,LB,IT,
      1 4HSTRS,4HE23 ,1,3)
      CALL DAL (NLIB,11,STR1(1297),0,0,KADL,IERR,NW,NE,LB,IT,
      1 4HSTRS,4HE23 ,1,4)
      CALL DAL (NLIB,11,STR1(1729),0,0,KADL,IERR,NW,NE,LB,IT,
      1 4HSTRS,4HE23 ,1,5)
      CALL DAL (NLIB,11,STR1(2161),0,0,KADL,IERR,NW,NE,LB,IT,
      1 4HSTRS,4HE23 ,1,6)
C
C   OBJECTIVE
C
      CALL DAL (NLIB,11,OBJP,0,0,KADL,IERR,NW,NE,LB,IT,
      *4HOBJS,4HAUS ,4HMASK,4HMASK)
C
C   EIGENMODES
C
      CALL DAL (NLIB,10,AMODE,0,0,KADR,IERR,NWDS,NE,LB,IT,
      1 4HVIBR,4HMODE,4HMASK,4HMASK)
C
C
      READ(2,*) ITER,NDV
      NCOEF=NELT*NMODE
      NLIM1=NDV+1
      NLIM2=NMODE*NLIM1
      NLIM3=NCOEF*NLIM1
      NLIM4=NDOF*NLIM1*NMODE

```

```

C
C IF ITER.EQ.0 CREATE GRDATA
C
      IF(ITER.GT.0)GO TO 2000
      DO 1000 I=1,NLIM2
1000   G1(I)=0.0
      DO 1001 I=1,NLIM4
1001   G2(I)=0.0
      DO 1002 I=1,NLIM3
1002   G3(I)=0.0
      DO 1003 I=1,NLIM1
      G4(I)=0.0
1003   CONTINUE
      WRITE(32,*)(G1(I),I=1,NLIM2),
      *(G2(I),I=1,NLIM4),
      *(G3(I),I=1,NLIM3),
      *(G4(I),I=1,NLIM1)
2000   CONTINUE
C
      REWIND 32
C IF ITER.GT.0 READ DATA FROM OLD GRDATA FILE
C
      READ(32,*)(G1(I),I=1,NLIM2),
      *(G2(I),I=1,NLIM4),
      *(G3(I),I=1,NLIM3),
      *(G4(I),I=1,NLIM1)
      REWIND 32
C
C STORE DATA
C
C OBJECTIVE
C
      G4(ITER+1)=OBJF
C
C FREQUENCY
C
      DO 2 I=1,NMODE
      FREQCY=SQRT(FREQ(I))/(2.*PI)
      K=(ITER*NMODE)+I
      G1(K)=FREQCY
2     CONTINUE
C
C EIGENMODES
C
      ID=ITER*NDOF*NMODE
      DO 4 I=1,NMODE
      KS=KADR + (I-1)*NSECTS(LB)
      CALL RIO(NLIB,2,2,KS,AMODE,LB)
      DO 6 J=1,NNODE
      DO 7 K=1,3
      ID=ID+1
      G2(ID)=AMODE(K,J)
7     CONTINUE
6     CONTINUE
4     CONTINUE
C
C STRESS COEFFICIENTS
C

```

```

      ID=ITER*NCOEF
      JC=0
      DO 8 I=1,NMODE
      ID1=(I-1)*NELT*6
      DO 9 J=1,NELT
      ID2=(J-1)*6 + 5 + ID1
      IDK=ID2+1
      ID=ID+1
      G3(ID)=STR1(IDK)
9      CONTINUE
8      CONTINUE
C
C      WRITE OBJECTIVE,EIGEN-INFO AND STRESS COEFFICIENTS
C
      WRITE(32,*)(G1(I),I=1,NLIM2),
      *(G2(I),I=1,NLIM4),
      *(G3(I),I=1,NLIM3),
      *(G4(I),I=1,NLIM1)
      REWIND 32
      STOP
      END
EOI ENCOUNTERED.
/

```



```

LIST, FN=EXTPLT
      PROGRAM EXTPLT (DECIS, DESIGN, CONDAT, FOUT, NODAL, ITER,
      *WPOS, WPOS1, WPOS2,
      *TAPE33=DESIGN, TAPE22=CONDAT, TAPE7=POUT, TAPE1=NODAL,
      *TAPE4=WPOS1, TAPE8=WPOS2,
      *TAPE31=DECIS, TAPE9=ITER, TAPE3=WPOS, INPUT, OUTPUT)

C
C *****
C
C THIS PROGRAM PROVIDES A NEW SET OF EXTRAPOLATED MODES
C EIGENFREQUENCIES AND RESPONSE COEFFICIENTS TO ANALYSIS
C
C PRABHAT HAJELA  JUNE 1985
C
C *****
C
      DIMENSION G1(100), G2(1500), G3(1100), G4(10), DD(60)
      DIMENSION GRDG(8, 1500), GRDG1(8, 1100), GRDG2(8, 10),
      *GRDOBJ(10)
      DIMENSION NODE(80), X(10), Y(10), XX(10), AMODE(6, 3, 80)
      DIMENSION G(1000), FREQ(10), DELT(10), VECN(1500)
      DIMENSION GMAS(54, 54), S1(100), S2(10000), STRS(72, 54, 1)
      DATA NMODE/6/, NDOF/240/, NELT/72/, NE41/10/,
      *NSNODE/40/, NNODE/80/
      OPEN(UNIT=7, FILE='POUT')
      OPEN(UNIT=1, FILE='NODAL')
      OPEN(UNIT=33, FILE='DESIGN')
      OPEN(UNIT=22, FILE='CONDAT')
      OPEN(UNIT=31, FILE='DECIS')
      OPEN(UNIT=9, FILE='ITER')
      OPEN(UNIT=3, FILE='WPOS')
      OPEN(UNIT=4, FILE='WPOS1')
      OPEN(UNIT=8, FILE='WPOS2')
      READ(9, *) ITER, NDV
      NCOEF=NELT*NMODE
      N1=NDOF*NMODE
      NLIM1=NDV+1
      NLIM2=NMODE*NLIM1
      NLIM3=NCOEF*NLIM1
      NLIM4=NDOF*NLIM1
      NSTR=NELT
      DO 40 I=1, 18
      DO 41 J=1, 18
      GMAS(I, J)=0.0
      IF(I.EQ.J) GMAS(I, J)=1.0
41  CONTINUE
40  CONTINUE
      READ(31, *) (X(I), I=1, NDV), (Y(I), I=1, NE41), FDCH
      READ(1, *) (NODE(I), I=1, NSNODE)
      READ(22, *) (G1(I), I=1, NMODE), (G2(I), I=1, N1),
      *(G3(I), I=1, NCOEF), G4(1),
      *(GRDOBJ(I), I=1, NDV),
      *((GRDG(I, J), I=1, NDV), J=1, N1),
      *((GRDG2(I, J), I=1, NDV), J=1, NMODE),
      *((GRDG1(I, J), I=1, NDV), J=1, NCOEF)

```

```

      DO 30 INN=1,NLIM1
      READ(33,*) (XX(I),I=1,NDV)
      REWIND 33
      IF (INN.EQ.1) GO TO 31
      XX(INN-1)=XX(INN-1)*(1.+FDCH)
31    CONTINUE
C
C    UPDATE STRESS COEFFICIENTS
C
      DO 2 I=1,NCOEF
      STR=G3(I)
      DO 4 J=1,NDV
      DELT(J)=XX(J)-X(J)
      STR=STR + GRDG1(J,I)*DELT(J)
4    CONTINUE
      G(I)=STR
2    CONTINUE
C
C    FREQUENCIES
C
      DO 6 I=1,NMODE
      EIG=G1(I)
      DO 8 J=1,NDV
      DELT(J)=XX(J)-X(J)
      EIG=EIG+GRDG2(J,I)*DELT(J)
8    CONTINUE
      FREQ(I)=EIG
6    CONTINUE
C
C    EIGENMODES
C
      DO 10 I=1,N1
      VEC=G2(I)
      DO 12 J=1,NDV
      DELT(J)=XX(J)-X(J)
      VEC=VEC+GRDG(J,I)*DELT(J)
12   CONTINUE
      VECN(I)=VEC
10   CONTINUE
      ID=0
      DO 14 I=1,NMODE
      DO 16 J=1,NNODE
      DO 17 K=1,3
      ID=ID+1
      AMODE(I,K,J)=VECN(ID)
17   CONTINUE
16   CONTINUE
14   CONTINUE
      DO 21 K=1,NMODE
      DO 20 I=1,NSNODE
      IF (INN.LE.3) THEN
      WRITE(3,1000) (AMODE(K,J,NODE(I)),J=1,3)
1000  FORMAT(3E15.8)

```

```

        GO TO 19
    ENDIF
    IF (INN.LE.6) THEN
        WRITE(4,1000) (AMODE(K,J,NODE(I)),J=1,3)
        GO TO 19
    ENDIF
    IF (INN.LE.9) THEN
        WRITE(8,1000) (AMODE(K,J,NODE(I)),J=1,3)
    ENDIF
19    CONTINUE
20    CONTINUE
21    CONTINUE
        IJ=(INN-1)*NMODE
        DO 50 IK=1,NMODE
            IJK=IJ+IK
50    S1(IJK)=FREQ(IK)
        IL=(INN-1)*NCOEF
        DO 51 IM=1,NCOEF
            ILM=IL+IM
51    S2(ILM)=G(IM)
30    CONTINUE
        JP=0
        DO 52 J=1,NLIM2
            DO 53 I=1,NELT
                DO 54 K=1,1
                    JP=JP+1
                    STRS(I,J,K)=S2(JP)
54    CONTINUE
53    CONTINUE
52    CONTINUE
        IC=NLIM2/18
        DO 61 IZ=1,54
61    DD(IZ)=0.01
        DO 60 I=1,IC
            WRITE(7,*)((GMAS(II,J),J=1,18),II=1,18)
            KP=(I-1)*18
            WRITE(7,*)(S1(KP+II),II=1,18)
            DO 55 IEL=1,NELT
                DO 56 K=1,1
                    WRITE(7,*)(STRS(IEI,IY,K),IY=KP+1,KP+18)
56    CONTINUE
55    CONTINUE
            WRITE(7,*)(DD(IZ),IZ=1,18)
60    CONTINUE
        STOP
        END
    EOI ENCOUNTERED.
/

```

```

LIST, FN=GRAD
      PROGRAM GRAD(DECIS, ITER, GRDATA, CONDAT, SECPROP, FLAG, OBDJ,
      *TAPE31=DECIS, TAPE30=ITER, TAPE32=GRDATA, TAPE22=CONDAT,
      *TAPE7=SECPROP, TAPE14=FLAG, TAPE2=OBDJ)
C
C *****
C
C THIS PROGRAM IS A PREPROCESSOR TO A GRADIENT COMPUTING
C SEGMENT - GRADIENTS OF EIGENVALUES, EIGENVECTORS AND
C STRESS COEFFICIENTS ARE COMPUTED
C
C PRABHAT HAJELA, JUNE 1985
C
C *****
C
      DIMENSION GRDG(8,1500), GRDOBJ(10), X(10), G1(100)
      *, G2(13000), G3(10000), G4(10), Y(10)
      *, GRDG1(8,1100), GRDG2(8,10)
      NMODE=6
      ND41=10
      NSTR=72
      NDOF=240
      NCOEF=NSTR*NMODE
      OPEN(UNIT=30, FILE='ITER')
      OPEN(UNIT=31, FILE='DECIS')
      OPEN(UNIT=7, FILE='SECPROP')
      OPEN(UNIT=22, FILE='CONDAT')
      READ(30, *) ITER, NDV
      REWIND 30
C
C READ DESIGN VARIABLES AND FINITE DIFFERENCE STEP SIZE
C
      READ(31, *) (X(I), I=1, NDV), (Y(I), I=1, ND41), FDCH
      ITER=ITER+1
C
C
C IF ITER.EQ.NDV+1 THEN ALL DV'S PERTURBED
C
      IF(ITER.EQ.NDV+1) GO TO 100
      IF(ITER.GE.1) X(ITER)=X(ITER)*(1.+FDCH)
C
C WRITE SPAR INPUT RUNSTREAM
C
      REWIND 7
      WRITE(7, 98)
98      FORMAT('EXQT TAB', /, 'BC')
      DO 1 I=1, NDV
      WRITE(7, *) I, X(I)
1      CONTINUE
      WRITE(7, 99)
99      FORMAT('SA')
      DO 2 I=1, ND41
      WRITE(7, *) I, Y(I)

```

```

2      CONTINUE
      WRITE(7,1010)
1010  FORMAT(' [XQT EXIT')
      REWIND 7
      WRITE(30,*) ITER,NDV
      GOTO 110
100   CONTINUE
C
C   COMPUTE GRADIENTS
C
      ITER=-1
      WRITE(30,*) ITER,NDV
      NLIM1=NDV+1
      NLIM2=NMODE*NLIM1
      NLIM3=NCOEF*NLIM1
      NLIM4=NDOF*NLIM1*NMODE
      OPEN(UNIT=32,FILE='GRDATA')
      READ(32,*)(G1(I),I=1,NLIM2),
      *(G2(I),I=1,NLIM4),
      *(G3(I),I=1,NLIM3),
      *(G4(I),I=1,NLIM1)
C
C   OBJECTIVE
C
      DO 10 I=1,NDV
      J1=I+1
      GRDOBJ(I)=(G4(J1)-G4(1))/(FDCH*X(I))
10    CONTINUE
C
C   FREQUENCY
C
      DO 25 J=1,NDV
      II=NMODE*J
      DO 20 I=1,NMODE
      II1=II+I
      GRDG2(J,I)=(G1(II1)-G1(I))/(FDCH*X(J))
20    CONTINUE
25    CONTINUE
C
C   STRESS COEFFICIENTS
C
      DO 27 J=1,NDV
      II=NCOEF*J
      DO 22 I=1,NCOEF
      II1=II+I
      GRDG1(J,I)=(G3(II1)-G3(I))/(FDCH*X(J))
22    CONTINUE
27    CONTINUE
C
C   EIGENMODES
C
      N1=NDOF*NMODE
      DO 29 J=1,NDV
      II=N1*J
      DO 24 I=1,N1
      II1=II+I
      GRDG(J,I)=(G2(II1)-G2(I))/(FDCH*X(J))
24    CONTINUE
29    CONTINUE
C

```

```

C  WRITE GRAD INFO
C
      WRITE(22,*) (G1(I), I=1, NMODE),
      *(G2(I), I=1, N1),
      *(G3(I), I=1, NCOEF), G4(1),
      *(GRDOBJ(I), I=1, NDV),
      *((GRDG(I, J), I=1, NDV), J=1, N1),
      *((GRDG2(I, J), I=1, NDV), J=1, NMODE),
      *((GRDG1(I, J), I=1, NDV), J=1, NCOEF)
C
      REWIND 22
      OPEN(UNIT=2, FILE='OSDJ')
      WRITE(2,*) G4(1), (GRDOBJ(I), I=1, NDV)
C
C EXIT FROM GRADIENT LOOP BY DECLARING TAPE14 AS LOCAL
C
      OPEN(UNIT=14, FILE='FLAG')
      WRITE(14,*) ITER
110  CONTINUE
      STOP
      END
EOI ENCOUNTERED.
/

```

```

LIST, FN=OBJFUN
      PROGRAM OBJFUN(DECIS, ITER, DESIGN, CVD1, CONMDT, OBDJ,
      *TAPE8=CVD1, TAPE10=DESIGN, TAPE16=CONMDT,
      *TAPE4=DECIS, TAPE7=ITER, TAPE2=OBDJ)
C
C*****
C
C  THIS PROGRAM COMPUTES AND WRITES THE SENSITIVITY
C  INFORMATION AS REQUIRED BY THE OPTIMIZATION
C  PROGRAM, CONOPT.
C
C  PRABHAT HAJELA  JULY 1985
C
CC *****
C
      DIMENSION A(12000), STR(1000), STRR(1000)
      DIMENSION Y(10), X(10), XX(10), TEM(1000)
      DIMENSION GSE(1000), GFF(1000), GRDOBJ(10), GRDB(10,200)
      DATA NSTR/72/, SIGAL/25000./, TSE/6.15168E+7/, PI/3.14159/,
      *TFF/6.15168E+7/, GAM5/24./, CEE/1.E+41/, ND41/10/
      OPEN(UNIT=8, FILE='CVD1')
      OPEN(UNIT=10, FILE='DESIGN')
      OPEN(UNIT=16, FILE='CONMDT')
      OPEN(UNIT=4, FILE='DECIS')
      OPEN(UNIT=7, FILE='ITER')
      OPEN(UNIT=2, FILE='OBDJ')
      READ(7, *) ITER, NDV
      READ(2, *) OBJ1, (GRDOBJ(I), I=1, NDV)
      READ(10, *) (X(I), I=1, NDV)
      READ(4, *) (XX(I), I=1, NDV), (Y(I), I=1, ND41), FDCH
      NLIM1=NDV+1
      NLIM2=NLIM1*NSTR
      NSTR1=1 + 2*NSTR
      NSTRSQ=NSTR1**2
      NDIM=(NSTRSQ+NSTR1)/2
      READ(8, *) N1
      DO 2 IJ=1, NLIM1
      READ(8, *) N1, (A(I), I=1, NDIM)
      IN=(IJ-1)*NSTR
      JCK=1
      DO 4 I=1, NSTR1-1
      TEM(I)=SQRT(A(JCK))
      JCK=JCK+NSTR1-(I-1)
4      CONTINUE
      DO 6 I=1, NSTR
      K=NSTR+I
      STR(I+IN)=TEM(I)
      STRR(I+IN)=TEM(K)
6      CONTINUE
2      CONTINUE
C
C  CONSTRAINT - SINGLE EXCURSION FAILURE
C

```

```

      DO 10 I=1,NLIM2
      STR(I)=STR(I)*100.
      STRR(I)=STRR(I)*100.
      FUN=(SIGAL**2)/(2.*STR(I)*STR(I))
      FUN=-FUN
      IF(FUN.LE.-675.0)FUN=-675.0
      IF(FUN.GE.741.0)FUN=741.0
10      GSE(I)=(TSE/PI)*(STRR(I)/STR(I))*EXP(FUN) - 1.
C
C   CONSTRAINT - FATIGUE FAILURE
C
      DO 12 I=1,NLIM2
      FUN=(TFF/(PI*CEE))*8.*GAM5
12      GFF(I)=(FUN*STRR(I)*(STR(I)**7)) - 1.
C
C   CONSTRAINT DERIVATIVES
C
      DO 14 I=1,NDV
      K=I*NSTR
      DO 16 J=1,NSTR
      GRDG(I,J)=(GSE(K+J)-GSE(J))/(FDCH*X(I))
16      CONTINUE
14      CONTINUE
      DO 18 I=1,NDV
      K=I*NSTR
      DO 20 J=NSTR+1,2*NSTR
      GRDG(I,J)=(GFF(K+J-NSTR)-GFF(J-NSTR))/(FDCH*X(I))
20      CONTINUE
18      CONTINUE
C
C   WRITE OBJECTIVE, CONSTRAINTS AND THEIR DERIVATIVES
C
      WRITE(16,*)(GSE(I),I=1,NSTR),
      *(GFF(I),I=1,NSTR),OBJ1,
      *((GRDG(I,J),I=1,NDV),J=1,2*NSTR),
      *(GRDOBJ(I),I=1,NDV)
C
      STOP
      END
EOI ENCOUNTERED.
/

```



```

LIST, FN=POST
  PROGRAM POST (DESIGN, DECIS, ITER, TAPE2=ITER,
    *TAPE7=DECIS, TAPE8=DESIGN)
C
C *****
C
C THIS PROGRAM UPDATES THE DECIS FILE AND CAN ALSO BE USED
C TO DETERMINE IF MODES NEED TO BE RECOMPUTED IN PROBLEM
C
C PRABHAT HAJELA JULY 1985
C
C *****
C
  DIMENSION X(10), Y(10), XX(10)
  DATA ND41/10/
  OPEN(UNIT=2, FILE='ITER')
  OPEN(UNIT=7, FILE='DECIS')
  OPEN(UNIT=8, FILE='DESIGN')
  READ(2, *) ITER, NDV
  READ(7, *) (XX(I), I=1, NDV), (Y(I), I=1, ND41), FDCH
  READ(8, *) (X(I), I=1, NDV)
  DO 2 I=1, NDV
2    XX(I)=X(I)
    REWIND 8
    REWIND 7
    WRITE(7, 100) (XX(I), I=1, NDV), (Y(I), I=1, ND41), FDCH
100  FORMAT(F10.4)
    STOP
    END
  EOI ENCOUNTERED.
/

LIST, FN=REDUC
  PROGRAM REDUC (CVDATA, TAPE3=CVDATA, OUTPUT)
C
C *****
C
C THIS PROGRAM REDUCES THE SIZE OF THE COVARIANCE MATRIX
C
C
CC
C PRABHAT HAJELA JULY 1985
C
C *****
C
  DIMENSION CV(145, 145)
  OPEN(UNIT=3, FILE='CVDATA')
  READ(3, *) N1
  READ(3, *) ((CV(I, J), J=1, N1), I=1, N1)
  REWIND 3
  WRITE(3, *) N1
  DO 2 I=1, N1
  2  WRITE(3, *) (CV(I, J), J=I, N1)
    CONTINUE
    CLOSE(UNIT=3)
    STOP
    END
  EOI ENCOUNTERED.
/

```

LIST, FN=NREPT
EXQT TAB

non-repeatable part of SPAR

START 80,4 5 6

MATC

1 10.5+6 .3 .1

2 10.5+6 .3 .1

JLOC

1	0.00	-67.50	3.78
2	0.00	-67.50	7.02
3	0.00	-37.50	10.80
4	0.00	-7.50	10.80
5	0.00	22.50	7.02
6	0.00	22.50	3.78
7	0.00	-7.50	0.00
8	0.00	-37.50	0.00
9	40.00	-81.57	3.89
10	40.00	-81.57	6.91
11	40.00	-53.61	10.43
12	40.00	-25.64	10.43
13	40.00	2.32	6.91
14	40.00	2.32	3.89
15	40.00	-25.64	0.37
16	40.00	-53.61	0.37
17	80.00	-95.64	4.00
18	80.00	-95.64	6.80
19	80.00	-69.71	10.07
20	80.00	-43.79	10.07
21	80.00	-17.86	6.80
22	80.00	-17.86	4.00
23	80.00	-43.79	0.73
24	80.00	-69.71	0.73
25	120.00	-109.71	4.11
26	120.00	-109.71	6.69
27	120.00	-85.82	9.70
28	120.00	-61.93	9.70
29	120.00	-38.04	6.69
30	120.00	-38.04	4.11
31	120.00	-61.93	1.10
32	120.00	-85.82	1.10
33	160.00	-123.78	4.22
34	160.00	-123.78	6.58
35	160.00	-101.92	9.33
36	160.00	-80.07	9.33
37	160.00	-58.22	6.58
38	160.00	-58.22	4.22
39	160.00	-80.07	1.47
40	160.00	-101.92	1.47
41	200.00	-137.84	4.33
42	200.00	-137.84	6.47
43	200.00	-118.03	8.97
44	200.00	-98.22	8.97
45	200.00	-78.40	6.47
46	200.00	-78.40	4.33

47	200.00	-98.22	1.83
48	200.00	-118.03	1.83
49	240.00	-151.91	4.44
50	240.00	-151.91	6.36
51	240.00	-134.14	8.60
52	240.00	-116.36	8.60
53	240.00	-98.58	6.36
54	240.00	-98.58	4.44
55	240.00	-116.36	2.20
56	240.00	-134.14	2.20
57	280.00	-165.98	4.55
58	280.00	-165.98	6.25
59	280.00	-150.24	8.23
60	280.00	-134.50	8.23
61	280.00	-118.76	6.25
62	280.00	-118.76	4.55
63	280.00	-134.50	2.57
64	280.00	-150.24	2.57
65	320.00	-180.05	4.66
66	320.00	-180.05	6.14
67	320.00	-166.35	7.87
68	320.00	-152.64	7.87
69	320.00	-138.94	6.14
70	320.00	-138.94	4.66
71	320.00	-152.64	2.93
72	320.00	-166.35	2.93
73	360.00	-194.12	4.77
74	360.00	-194.12	6.03
75	360.00	-182.45	7.50
76	360.00	-170.79	7.50
77	360.00	-159.12	6.03
78	360.00	-159.12	4.77
79	360.00	-170.79	3.30
80	360.00	-182.45	3.30

CON 1

ZERO 1,2,3;1, 8

BC

1 1.567

2 .7176

3 0.1

4 1.567

5 .7178

6 .1

7 .1

8 .1

SA

1 .05

2 .052

3 .05

4 .05

5 .05

6 .052

7 .05

```

8 .05
9 .05
10 .0675
[ XQT ELD
  E41
NSECT=1
2 10 11 3 1 2 3
NSECT=2
18 26 27 19 1 2 3
NSECT=3
34 42 43 35 1 2 3
NSECT=4
50 58 59 51 1 3 3
NSECT=5
1 9 16 8 1 2
8 16 15 7 1 2 2
NSECT=6
17 25 32 24 1 2
24 32 31 23 1 2 2
NSECT=7
33 41 48 40 1 2
40 48 47 39 1 2 2
NSECT=8
49 57 64 56 1 3
56 64 63 55 1 3 2
  NMAT=2
  NSECT= 9
    9  16  11  10
    16  15  12  11
    15  14  13  12
    17  24  19  18
    24  23  20  19
    23  22  21  20
    25  32  27  26
    32  31  28  27
    31  30  29  28
    33  40  35  34
    40  39  36  35
    39  38  37  36
    41  48  43  42
    48  47  44  43
    47  46  45  44
    49  56  51  50
    56  55  52  51
    55  54  53  52
    57  64  59  58
    64  63  60  59
    63  62  61  60
    65  72  67  66
    72  71  68  67
    71  70  69  68
    73  80  75  74
    80  79  76  75

```

```

    79 78 77 76
NSECT=10
1 9 10 2 1 9
6 14 13 5 1 9
E23
NMAT=1
NSECT= 1
1 9 1 2 2 7
6 14 1 2 2 1
NSECT=2
22 30 1 2 2 1
17 25 1 2 2 7
NSECT=3
38 46 1 2 2 1
33 41 1 2 2 7
NSECT=4
2 10 1 2 4 1
NSECT=5
18 26 1 2 4 1
NSECT=6
34 42 1 2 4 1
NSECT=7
54 62 1 3 2 1
49 57 1 3 2 7
NSECT=8
50 58 1 3 4 1
IXQT EXIT
EOI ENCOUNTERED.
/

```

```

LIST,FN=REPT
[XQT E
  RESET G=386.
[XQT TOPO
[XQT EKS
[XQT K
[XQT INV
[XQT EIG
RESET INIT=8,NREQ=6,HIST=0
[XQT DCU
PRINT 1 VIBR EVAL
[XQT VPRT
PRINT VIBR MODE
[XQT AUS
SYSVEC;UNIT VEC
I=1;J=1,80;1.0
DEFINE UN=UNIT VEC
DEFINE DM=DEM DIAG
OBJF=XTY(UN,DM)
DEFINE V1=VIBR MODE 1 1 1,6
XDIS=UNION(V1)
[XQT GSF
SOURCE=XDIS AUS
[XQT DCU
TOC 1
[XQT EXIT
EOI ENCOUNTERED.
/

```

repeatable part of SPAR

```

LIST,FN=SECPROP
[XQT TAB
BC
  1 1.0923
  2 .324
  3 .3
  4 .3
  5 .3
  6 .3
  7 .3
  8 .3
SA
  1 .05
  2 .05
  3 .05
  4 .05
  5 .05
  6 .05
  7 .05
  8 .05
  9 .05
 10 .065
[XQT EXIT
EOI ENCOUNTERED.
/

```

new section properties
file created in GRAD

```

LIST,FN=TAP2G
-2
PHWING ONESIX
$INPUT NM=18, NR=0, NC=0, NK=7, ISPLANE=3, C=69.58,
  NLOAD=72, IDCM=1, IAPLT=0, ISTABLE=1, IGUST=1,
  BN=.30,.65, NCOEF=5, NCOL=0,6*1, NKK=7*7,
  ICONSYS=0, NS=0, ISELECT=1, ICSACT=1, IBLOCK=2, KVAR=3,
  GL=30000., ISPECT=2, IPRINT=1, ISOUT=0,
  V0=8876.6, RH00=0., DV=1.873E-9, NV=0, NG=1,
  NINT=5, RFLOW=0., RFCUT=1.0, UU=8876.56, NVEL=1, RHO=5.716E-8,
  IFLPLT=0, IFRFPLT=1$
ALL 1 0
END
$ACTINP $
$SELECT NMODES=6 , NCNEW=0, NDC=1,2,3,4,5,6$
$PLTSEL $
0
-2
MODES SEVEN TWELVE
$INPUT NM=18, NR=0, NC=0, NK=7, ISPLANE=3, C=69.58,
  NLOAD=72, IDCM=1, IAPLT=0, ISTABLE=1, IGUST=1,
  BN=.30,.65, NCOEF=5, NCOL=0,6*1, NKK=7*7,
  ICONSYS=0, NS=0, ISELECT=1, ICSACT=1, IBLOCK=2, KVAR=3,
  GL=30000., ISPECT=2, IPRINT=1, ISOUT=0,
  V0=8876.6, RH00=0., DV=1.873E-9, NV=0, NG=1,
  NINT=5, RFLOW=0., RFCUT=1.0, UU=8876.56, NVEL=1, RHO=5.716E-8,
  IFLPLT=0, IFRFPLT=1$
ALL 1 0
END
$ACTINP $
$SELECT NMODES=6, NCNEW=0, NDC=7,8,9,10,11,12$
$PLTSEL $
0
-2
MODES THIRTEEN EIGHTEEN
$INPUT NM=18, NR=0, NC=0, NK=7, ISPLANE=3, C=69.58,
  NLOAD=72, IDCM=1, IAPLT=0, ISTABLE=1, IGUST=1,
  BN=.30,.65, NCOEF=5, NCOL=0,6*1, NKK=7*7,
  ICONSYS=0, NS=0, ISELECT=1, ICSACT=1, IBLOCK=2, KVAR=3,
  GL=30000., ISPECT=2, IPRINT=1, ISOUT=0,
  V0=8876.6, RH00=0., DV=1.873E-9, NV=0, NG=1,
  NINT=5, RFLOW=0., RFCUT=1.0, UU=8876.56, NVEL=1, RHO=5.716E-8,
  IFLPLT=0, IFRFPLT=1$
ALL 1 0
END
$ACTINP $
$SELECT NMODES=6, NCNEW=0, NDC=13,14,15,16,17,18$
$PLTSEL $
0
-2
MODES NINETEEN TWENTYFOUR
$INPUT NM=18, NR=0, NC=0, NK=7, ISPLANE=3, C=69.58,
  NLOAD=72, IDCM=1, IAPLT=0, ISTABLE=1, IGUST=1,
  BN=.30,.65, NCOEF=5, NCOL=0,6*1, NKK=7*7,
  ICONSYS=0, NS=0, ISELECT=1, ICSACT=1, IBLOCK=2, KVAR=3,
  GL=30000., ISPECT=2, IPRINT=1, ISOUT=0,
  V0=8876.6, RH00=0., DV=1.873E-9, NV=0, NG=1,

```

```

NINT=5,RFLOW=0.,RFCUT=1.0,UU=8876.56,NVEL=1,RHO=5.716E-8,
IFLPLT=0,IFRFPLT=1$
ALL 2 0
END
$ACTINP $
$SELECT NMODES=6,NCNEW=0,NOC=1,2,3,4,5,6$
$PLTSEL $
0
-2
MODES TWENTYFIVE THIRTY
$INPUT NM=18, NR=0, NC=0, NK=7, ISPLANE=3, C=69.58,
NLOAD=72, IDCM=1, IAPLT=0, ISTABLE=1, IGUST=1,
BN=.30,.65, NCOEF=5, NCOL=0,6*1, NKK=7*7,
ICONSYS=0, NS=0, ISELECT=1, ICSACT=1, IBLOCK=2, KVAR=3,
GL=30000., ISPECT=2, IPRINT=1, ISOUT=0,
VO=8876.6, RHO=0., DV=1.873E-9, NV=0, NG=1,
NINT=5, RFLOW=0., RFCUT=1.0, UU=8876.56, NVEL=1, RHO=5.716E-8,
IFLPLT=0, IFRFPLT=1$
ALL 2 0
END
$ACTINP $
$SELECT NMODES=6,NCNEW=0,NOC=7,8,9,10,11,12$
$PLTSEL $
0
-2
MODES THIRTYONE THIRTSIX
$INPUT NM=18, NR=0, NC=0, NK=7, ISPLANE=3, C=69.58,
NLOAD=72, IDCM=1, IAPLT=0, ISTABLE=1, IGUST=1,
BN=.30,.65, NCOEF=5, NCOL=0,6*1, NKK=7*7,
ICONSYS=0, NS=0, ISELECT=1, ICSACT=1, IBLOCK=2, KVAR=3,
GL=30000., ISPECT=2, IPRINT=1, ISOUT=0,
VO=8876.6, RHO=0., DV=1.873E-9, NV=0, NG=1,
NINT=5, RFLOW=0., RFCUT=1.0, UU=8876.56, NVEL=1, RHO=5.716E-8,
IFLPLT=0, IFRFPLT=1$
ALL 2 0
END
$ACTINP $
$SELECT NMODES=6,NCNEW=0,NOC=13,14,15,16,17,18$
$PLTSEL $
0
-2
MODES THIRTYSEVEN FORTYTWO
$INPUT NM=18, NR=0, NC=0, NK=7, ISPLANE=3, C=69.58,
NLOAD=72, IDCM=1, IAPLT=0, ISTABLE=1, IGUST=1,
BN=.30,.65, NCOEF=5, NCOL=0,6*1, NKK=7*7,
ICONSYS=0, NS=0, ISELECT=1, ICSACT=1, IBLOCK=2, KVAR=3,
GL=30000., ISPECT=2, IPRINT=1, ISOUT=0,
VO=8876.6, RHO=0., DV=1.873E-9, NV=0, NG=1,
NINT=5, RFLOW=0., RFCUT=1.0, UU=8876.56, NVEL=1, RHO=5.716E-8,
IFLPLT=0, IFRFPLT=1$
ALL 3 0
END
$ACTINP $
$SELECT NMODES=6,NCNEW=0,NOC=1,2,3,4,5,6$
$PLTSEL $

```



```

0
-2
MODES FORTYTHREE FORTYEIGHT
$INPUT NM=18, NR=0, NC=0, NK=7, ISPLANE=3, C=69.58,
  NLOAD=72, IDCM=1, IAPLT=0, ISTABLE=1, IGUST=1,
  BN=.30,.65, NCOEF=5, NCOL=0,6*1, NKK=7*7,
  ICONSYS=0, NS=0, ISELECT=1, ICSACT=1, IBLOCK=2, KVAR=3,
  GL=30000., ISPECT=2, IPRINT=1, ISOUT=0,
  VO=8876.6, RHOO=0., DV=1.873E-9, NV=0, NG=1,
  NINT=5, RFLOW=0., RFCUT=1.0, UU=8876.56, NVEL=1, RHO=5.716E-8,
  IFLPLT=0, IFRFPLT=1$
ALL 3 0
END
$ACTINP $
$SELECT NMODES=6, NCNEW=0, NOC=7,8,9,10,11,12$
$PLTSEL $
0
-2
MODES FORTYNINE FIFTYFOUR
$INPUT NM=18, NR=0, NC=0, NK=7, ISPLANE=3, C=69.58,
  NLOAD=72, IDCM=1, IAPLT=0, ISTABLE=1, IGUST=1,
  BN=.30,.65, NCOEF=5, NCOL=0,6*1, NKK=7*7,
  ICONSYS=0, NS=0, ISELECT=1, ICSACT=1, IBLOCK=2, KVAR=3,
  GL=30000., ISPECT=2, IPRINT=1, ISOUT=0,
  VO=8876.6, RHOO=0., DV=1.873E-9, NV=0, NG=1,
  NINT=5, RFLOW=0., RFCUT=1.0, UU=8876.56, NVEL=1, RHO=5.716E-8,
  IFLPLT=0, IFRFPLT=1$
ALL 3 0
END
$ACTINP $
$SELECT NMODES=6, NCNEW=0, NOC=13,14,15,16,17,18$
$PLTSEL $
0
12
EOI ENCOUNTERED.
/

```

```

LIST, FN=TAPE31
PHWING TEST MODEL
ANYTHING
(3E15.8)
$DLINFT NSECTNS=1, NSECTNA=1, NDF=3, NNODES=40, NNODET=40,
  IDLAT=1, NELAST=18, IPLTMS=0,
  IPRINT=0, ISYM=+1,
  NPMX=40, IPLTBOX=0, IPLTNOD=0, SCX=30., SCY=30., IDCM=1, ITOC=1$
DISP -1 1
MODES 1 1
HHD 1 1
SPLINE 1 1
END
1 40 1 0. 0. 1.
1 48 1
  67.5000    0.0000    1    3    -5    4
  37.5000    0.0000    2    3    -5    4
   7.5000    0.0000    3    3    -5    4
 -22.5000    0.0000    4    3    -5    4
  81.5700   40.0000    5    3    -5    4
  53.6100   40.0000    6    3    -5    4
  25.6400   40.0000    7    3    -5    4
  -2.3200   40.0000    8    3    -5    4
  95.6400   80.0000    9    3    -5    4
  69.7100   80.0000   10    3    -5    4
  43.7900   80.0000   11    3    -5    4
  17.8600   80.0000   12    3    -5    4
 109.7100  120.0000   13    3    -5    4
   85.8200  120.0000   14    3    -5    4
   61.9300  120.0000   15    3    -5    4
   38.0400  120.0000   16    3    -5    4
  123.7800  160.0000   17    3    -5    4
  101.9200  160.0000   18    3    -5    4
   80.0700  160.0000   19    3    -5    4
   58.2200  160.0000   20    3    -5    4
  137.8400  200.0000   21    3    -5    4
  118.0300  200.0000   22    3    -5    4
   98.2200  200.0000   23    3    -5    4
   78.4000  200.0000   24    3    -5    4
  151.9100  240.0000   25    3    -5    4
  134.1400  240.0000   26    3    -5    4
  116.3600  240.0000   27    3    -5    4
   98.5800  240.0000   28    3    -5    4
  165.9800  280.0000   29    3    -5    4
  150.2400  280.0000   30    3    -5    4
  134.5000  280.0000   31    3    -5    4
  118.7600  280.0000   32    3    -5    4
  180.0500  320.0000   33    3    -5    4
  166.3500  320.0000   34    3    -5    4
  152.6400  320.0000   35    3    -5    4
  138.9400  320.0000   36    3    -5    4
  194.1200  360.0000   37    3    -5    4
  182.4500  360.0000   38    3    -5    4
  170.7900  360.0000   39    3    -5    4
  159.1200  360.0000   40    3    -5    4
EOI ENCOUNTERED.

```

```

LIST, FN=TAPE32
PHWING TEST MODEL
ANYTHING
(3E15.8)
$DLINPT NSECTNS=1, NSECTNA=1, NDF=3, NNODES=40, NNODET=40,
  IDLAT=1, NELAST=6, IPLTMS=0,
  IPRINT=0, ISYM=+1,
  NPMX=40, IPLTBOX=0, IPLTNOD=0, SCX=30., SCY=30., IDCM=1, ITOC=1$
DISP -1 2
MODES 2 2
HHD 2 2
SPLINE 2 2
END
1 40 1 0. 0. 1.
1 48 1
  67.5000    0.0000    1    3    -5    4
  37.5000    0.0000    2    3    -5    4
   7.5000    0.0000    3    3    -5    4
 -22.5000    0.0000    4    3    -5    4
  81.5700   40.0000    5    3    -5    4
  53.6100   40.0000    6    3    -5    4
  25.6400   40.0000    7    3    -5    4
  -2.3200   40.0000    8    3    -5    4
  95.6400   80.0000    9    3    -5    4
  69.7100   80.0000   10    3    -5    4
  43.7900   80.0000   11    3    -5    4
  17.8600   80.0000   12    3    -5    4
 109.7100  120.0000   13    3    -5    4
  85.8200  120.0000   14    3    -5    4
  61.9300  120.0000   15    3    -5    4
  38.0400  120.0000   16    3    -5    4
 123.7800  160.0000   17    3    -5    4
 101.9200  160.0000   18    3    -5    4
  80.0700  160.0000   19    3    -5    4
  58.2200  160.0000   20    3    -5    4
 137.8400  200.0000   21    3    -5    4
 118.0300  200.0000   22    3    -5    4
   98.2200  200.0000   23    3    -5    4
   78.4000  200.0000   24    3    -5    4
 151.9100  240.0000   25    3    -5    4
 134.1400  240.0000   26    3    -5    4
 116.3600  240.0000   27    3    -5    4
   98.5800  240.0000   28    3    -5    4
 165.9800  280.0000   29    3    -5    4
 150.2400  280.0000   30    3    -5    4
 134.5000  280.0000   31    3    -5    4
 118.7600  280.0000   32    3    -5    4
 180.0500  320.0000   33    3    -5    4
 166.3500  320.0000   34    3    -5    4
 152.6400  320.0000   35    3    -5    4
 138.9400  320.0000   36    3    -5    4
 194.1200  360.0000   37    3    -5    4
 182.4500  360.0000   38    3    -5    4
 170.7900  360.0000   39    3    -5    4
 159.1200  360.0000   40    3    -5    4
EOI ENCOUNTERED.

```

```

LIST, FN=TAPE33
PHWING TEST MODEL
ANYTHING
(3E15.8)
$DLINPT NSECTNS=1, NSECTNA=1, NDF=3, NNODES=40, NNODET=40,
  IDLAT=1, NELAST=6, IPLTMS=0,
  IFRINT=0, ISYM=+1,
  NPMX=40, IPLTBOX=0, IPLTNOD=0, SCX=30., SCY=30., IDCM=1, ITOC=1$
DISP -1 3
MODES 3 3
HHD 3 3
SPLINE 3 3
END
1 40 1 0. 0. 1.
1 48 1
  67.5000    0.0000    1    3    -5    4
  37.5000    0.0000    2    3    -5    4
   7.5000    0.0000    3    3    -5    4
 -22.5000    0.0000    4    3    -5    4
  81.5700   40.0000    5    3    -5    4
  53.6100   40.0000    6    3    -5    4
  25.6400   40.0000    7    3    -5    4
  -2.3200   40.0000    8    3    -5    4
  95.6400   80.0000    9    3    -5    4
  69.7100   80.0000   10    3    -5    4
  43.7900   80.0000   11    3    -5    4
  17.8600   80.0000   12    3    -5    4
 109.7100  120.0000   13    3    -5    4
  85.8200  120.0000   14    3    -5    4
  61.9300  120.0000   15    3    -5    4
  38.0400  120.0000   16    3    -5    4
 123.7800  160.0000   17    3    -5    4
 101.9200  160.0000   18    3    -5    4
  80.0700  160.0000   19    3    -5    4
  58.2200  160.0000   20    3    -5    4
 137.8400  200.0000   21    3    -5    4
 118.0300  200.0000   22    3    -5    4
  98.2200  200.0000   23    3    -5    4
  78.4000  200.0000   24    3    -5    4
 151.9100  240.0000   25    3    -5    4
 134.1400  240.0000   26    3    -5    4
 116.3600  240.0000   27    3    -5    4
  98.5800  240.0000   28    3    -5    4
 165.9800  280.0000   29    3    -5    4
 150.2400  280.0000   30    3    -5    4
 134.5000  280.0000   31    3    -5    4
 118.7600  280.0000   32    3    -5    4
 180.0500  320.0000   33    3    -5    4
 166.3500  320.0000   34    3    -5    4
 152.6400  320.0000   35    3    -5    4
 138.9400  320.0000   36    3    -5    4
 194.1200  360.0000   37    3    -5    4
 182.4500  360.0000   38    3    -5    4
 170.7900  360.0000   39    3    -5    4
 159.1200  360.0000   40    3    -5    4
EOI ENCOUNTERED.
/

```

```

LIST,FN=TAPEST
PHWING TEST MODEL
$DLATINP ACAP=22500.0,REFCHD=69.44,
  FMACH=.700,
  NDELT=1,NP=1,NB=0,NRF=7,RFREQ=0.0,0.05,0.15,0.30,0.5,0.75,1.05,
  NSTRIP=12,NSV=0,NBV=0,NMODES=18,NDATA=0,
  NELAST=18,REFSPN=1.0,NBOX=48,NSNC=65,
  XZERO=-22.5,NR=0,
  NC=0,IDCM=1,ITOC=1 $
HHD 1 0
AERO 1 1
AIC 0 1
END
-22.5 67.5 159.12 194.12 0.0 360.0
7.02 69.51 13 5 1.0
0.0 0.25 0.5 0.75 1.0
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.666 0.732 0.798 0.864 0.93 1.0
1 4 5 8 9 12 13 16 17 20 21 24
25 28 29 32 33 36 37 40 41 44 45 48
SECOND CASE
$DLATINP ACAP=22500.0,REFCHD=69.44,
  FMACH=.700,
  NDELT=1,NP=1,NB=0,NRF=7,RFREQ=0.0,0.05,0.15,0.30,0.5,0.75,1.05,
  NSTRIP=12,NSV=0,NBV=0,NMODES=18,NDATA=0,
  NELAST=18,REFSPN=1.0,NBOX=48,NSNC=65,
  XZERO=-22.5,NR=0,
  NC=0,IDCM=1,ITOC=2 $
HHD 2 0
AERO 2 2
AIC 1 0
END
-22.5 67.5 159.12 194.12 0.0 360.0
7.02 69.51 13 5 1.0
0.0 0.25 0.5 0.75 1.0
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.666 0.732 0.798 0.864 0.93 1.0
1 4 5 8 9 12 13 16 17 20 21 24
25 28 29 32 33 36 37 40 41 44 45 48
THIRD CASE
$DLATINP ACAP=22500.0,REFCHD=69.44,
  FMACH=.700,
  NDELT=1,NP=1,NB=0,NRF=7,RFREQ=0.0,0.05,0.15,0.30,0.5,0.75,1.05,
  NSTRIP=12,NSV=0,NBV=0,NMODES=18,NDATA=0,
  NELAST=18,REFSPN=1.0,NBOX=48,NSNC=65,
  XZERO=-22.5,NR=0,
  NC=0,IDCM=1,ITOC=3 $
HHD 3 0
AERO 3 3
AIC 1 0
END
-22.5 67.5 159.12 194.12 0.0 360.0
7.02 69.51 13 5 1.0
0.0 0.25 0.5 0.75 1.0
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.666 0.732 0.798 0.864 0.93 1.0
1 4 5 8 9 12 13 16 17 20 21 24
25 28 29 32 33 36 37 40 41 44 45 48
EOI ENCOUNTERED.
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16. Abstract The present work is a first step towards establishing an optimization capability for sizing airframe structures that are subjected to a combination of deterministic and random flight loads. The random vibration environment introduces the need for selecting a statistical process that best describes the random loads and permits computation of the dynamic response parameters of interest. Furthermore, it requires a formulation of design constraints that would minimize the conservativeness in the design and retain computational viability. In the present work, the random loads are treated as a stationary, homogeneous process with a Gaussian probability distribution. This report discusses the formulation of the analysis problem, the structure of the optimization programming system and a representative numerical example.					
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